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CHEMICAL ADDENDA:

BEING A BRIEF EXPOSITION OF THE SALIENT FEATURES OF

MODERN CHEMISTRY,

COMPILED CHIEFLY FROM THE PAPERS OF
BRODIE, DALTON, FRANKLAND,
GERHARDT, WOLCOTT GIBBS, HOFMANN, KEKULÉ,
ODLING, WILLIAMSON, WURTZ, ETC.;

DESIGNED AS
AN APPENDIX
TO
Elementary Text-Books on the Science.

BY THE
REV. B. W. GIBSONE,
M. A. CAMBS., B. SC. LOND., F. C. S.,
LECTURER IN CHEMISTRY AT THE CITY OF LONDON COLLEGE).

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PREFACE.

This little Treatise was intended for the use of the Class studying Elementary Chemistry at the City of London College: it may, however, be found serviceable by other teachers, as its contents—compilations chiefly from the recent papers or lectures of various Professors of eminence—have not yet found their way in a collected form into most Text-books accessible to the ordinary student.

As its special object is to present succinctly to his consideration those changes in theory, notation, and nomenclature characterising MODERN CHEMISTRY, it presupposes an acquaintance with the elementary principles and leading facts of the Science; and therefore introduces such definitions and explanations only as are necessary to give a unity and connectedness to the design, and has no pretension to any exhaustive treatment of this vast subject.

Its contents, as may be readily gathered from the marginal headings, are explanations of the terms, Elements; Radicle; Particle; Substitution; Equivalent or Combining Numbers; Atomic Theory of Dalton with Illustrations; Constant and Multiple Proportions; Constitution of Water; Double Atoms of Water ; Double Atoms of Oxygen ; Duplicatio of Atomic Numbers ; Advantages ; Objections Transformation of Formulæ; Atomicity ; Classification of Elements ; Molecule and Atom Contrasted Law of Even Numbers ; Volume of Molecule ; Combination by Volume ; Gerhardt's Types ; Gerhardt' Classification ; Unitary System ; Dualistic System Binary System ; Three Notations Contrasted Gmelin's Nomenclature ; Decimal Measures.

Since most of those who peruse this brochure wil be habituated to the old notation, the arguments ar expressed in this customary form up to such a poin in the Treatise as the newer methods are explained after which the modern symbolization is adopted.

It is recommended that first the text should b read and mastered, till which time the notes, containing frequently extensions of or exceptions from th general laws, should be postponed, as they involve more thorough comprehension of the theories introduced.

Some defects and omissions must suggest themselves to experienced Chemists in my humble attemp at the popularization of these important ideas, whic have been recently found so effective in giving system to the disconnected facts and disjointed theorie of the science. It is trusted that, while such preceptors yield a generous criticism, considering th difficulty of the undertaking, they will also point ou such errors as endanger the utility of the followin pages.

B. W. G.

Eaton-square, June, 1866.

CHEMICAL ADDENDA.

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Scope of thi Science.

CHEMISTRY is the science which treats of the union of unlike kinds of matter to form new compounds, or conversely of the resolution of such compounds into their simpler constituents.

Elements.

Those bodies which chemists cannot decompose or resolve into simpler bodies are called *elements*, all others are termed *compounds*.

There are about sixty-one elements at present known; these, together with their symbols, are enumerated at *page* 12.

Radicle.

Some compounds seem to play the part of elements, so intimately are their constituents associated; such bodies, *e.g.*, C_4H_5, C_2N, are styled *radicles* (Lat. radicula, dim. of radix.)

Particle.

Particle is a very small portion of matter, either divisible or indivisible (particula, Lat. dim. from pars).

In chemical elements or compounds any particle has *pro ratâ* the same inherent qualities as the whole from which it is derived; not so a particle of an ordinary mixture.

Substitutio

Many (some say all) instances of chemical action consist in the substitution of one element for another in a compound, *e.g.*—

$$CuCl + Fe = FeCl + Cu$$

$$i.e. \left\{\begin{matrix}\text{Chloride}\\ \text{of}\\ \text{Copper.}\end{matrix}\right\} \text{ and Iron produce } \left\{\begin{matrix}\text{Chloride}\\ \text{of}\\ \text{Iron.}\end{matrix}\right\} \text{ and Copper.}$$

where we find by experiment that 31·75 parts of copper are replaced by 28 of iron, the latter *combining* with the 35·5 of chlorine previously associated with the copper. Or

$$HO + Fe = FeO + H \rightarrow$$

$$\text{Water and Iron produce } \left\{\begin{matrix}\text{Oxide of}\\ \text{Iron}\end{matrix}\right\} \text{ and Hydrogen,}$$

where 1 part of hydrogen (united with 8 of oxygen to form water) is replaced by 28 of iron, the latter appropriating to itself the oxygen.

Equivalent or Combining Numbers.

Hence 31·75 parts of copper were said to be *equivalent* to 28 parts of iron, and 28 of iron to 1 of hydrogen, and the *combining* Nos. of hydrogen, iron, copper, chlorine, were said to be in the ratios 1 : 28 : 31·75 : 35·5.

From a consideration of the aggregate of many instances o combinations and replacements chemists after a long experience drew up a table of the numbers representing the weights o the elements which will each replace or combine with 1 part of hydrogen (the lightest and most saturative element) and which therefore will mutually replace each other, to wit—

Hydrogen	1	Molybdenum	48
Carbon	6	Cadmium	56
Oxygen	8	Tin	59
Nitrogen	14	Arsenic	75
Silicon	14	Bromine	80
Sulphur	16	Tungsten	92
Fluorine	19	Mercury	100
Calcium	20	Silver	108
Sodium	23	Antimony	122
Iron	28	Iodine	127
Phosphorus	31	Bismuth	210

Manganese	27½	Tellurium	64½
Cobalt	29½	Barium	68½
Nickel	29½	Osmium	99½
Chlorine	35½	Lead	103½

Aluminium	13¾	Selenium	39¾
Copper	31¾	Strontium	43¾
Zinc	32¾		

These are *now* commonly called the *equivalent* or *combining numbers* of the elements; but up to the last fifteen years they were also called indifferently *atomic* numbers. The origin of this last term we will now explain :—

Atom.

Definition.—An *atom* (of an element or chemical compound) is an ultimate particle, so indefinitely small as to be incapable of farther division (ἄτομος) without destroying its quality.

Dalton and his disciples supposed* that the atoms of the

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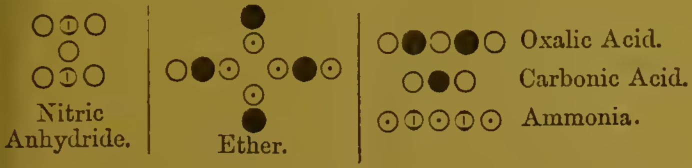
* Dalton himself did not suppose the ultimate atoms to have the same size.

Atomic Theory.

elements had the same *size* and *shape*, but different inappreciably small *weights*, viz. those proportionate to their combining numbers, and that when they united to form compounds they were grouped together symmetrically and integrally (never fractionally, being indivisible) according to some simple geometrical rule, *e.g.*—



The weight of any such compound atom was the sum of the weights of its constituent infinitesimal atoms, and was therefore also itself infinitesimally small, but was determinate and fixed in the ratios of the weights of its components.

Finite Mass.

A *finite* mass of any *element* was thus supposed to be the aggregation of an infinite number of such indefinitely minute similar elementary atoms.*

In like manner a *finite* mass of any *compound* body was regarded as the sum of an infinite number of similar compound atoms; it preserved, therefore, the same proportionality of constitution as its integrant atoms, viz. the proportion of the combining numbers of the elements (or of some simple multiples of them) united in such compound atoms.

Illustrations.

As a rough illustration to aid in the conception of such abstractions, suppose that the ultimate atoms of hydrogen, oxygen, chlorine, and copper weigh respectively

1	millionth	of a grain.
8	,,	,,
$35\frac{1}{2}$	,,	,,
$31\frac{3}{4}$	,,	,,

then the atom of water (HO) would weigh (1 + 8) 9 millionths.
of hydrochloric acid (HCl) ($1 + 35\frac{1}{2}$) $36\frac{1}{2}$ millionths.
of protoxide of copper (CuO) ($31\frac{3}{4} + 8$) $39\frac{3}{4}$ millionths.
of suboxide (Cu_2O) ($2 \times 31\frac{3}{4} + 8$) or $71\frac{1}{2}$ millionths.
of hydrated oxide of copper (CuO + 2HO) ($39\frac{3}{4} + 2 \times 9$) $57\frac{3}{4}$ millionths,

all inappreciably small quantities. Conceive, however, such minute compound atoms repeated each 1,000,000 times, and we obtain the finite and appreciable, though small masses,

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* Placed at equal distances from each other, and having the interstices occupied by an imponderable ether.

9	grs. of	Water	$71\frac{1}{2}$	grs. of	Cu_2O
$36\frac{1}{2}$	,,	HCl	$57\frac{3}{4}$	,,	CuO,2HO
$39\frac{3}{4}$	,,	CuO			

In all of these finite masses of compounds the same elements are associated in the same invariable proportion as in their originating groups of atoms.

Constant and Multiple Proportions.

This hypothesis accounted elegantly for the observed facts of the doctrines of constant and of multiple proportions as previously determined, viz. :—

I. The constituents A, B, C, &c. of any chemical compound unite in a ratio a : b : c, &c. invariable as to weight.

II. If a of A unite with b of B to form one compound, and a of A unite with c of C to form another, then if B is capable of combining with C, in all such combinations a weight mb of B will unite with nc of C, where m and n are very simple integers.

The atomic theory of Dalton is of course incapable of direct demonstration, owing to its dealing with magnitudes beneath man's observation, and indeed with metaphysical notions rather than with entities.

Constitution of Water.

Believing that water was the most abundant and important substance on the earth, and that its components H and O united only in the proportion 1 : 8, it was natural that Dalton and his school should regard this as the ratio of their atomic weights, and water as a protoxide H O (or using the Daltonian symbols ⊙ ○) containing one atom of each element.

Starting on this supposition it was not difficult to deduce by analogy that the weights of the atoms of the remaining elements were as recorded on *page* 6, and identical with the combining or equivalent weights.

But since his time a second compound of H and O has been discovered—the so-called * binoxide of hydrogen (HO_2)

Double Atoms of Water.

At the same time it has been perceived that in almost all reactions in which water was the agent or resultant that (16 + 2) parts or two old atoms always travelled in company, *e.g.*

$$\begin{array}{ccccc} C_2H_2O_4 & = & C_2O_2 & + & 2HO \\ \text{Formic Ac.} & & \text{Carb. Ox.} & & \text{Water.} \\ C_4H_6O_2 & = & C_4H_4 & + & 2HO \\ \text{Alcohol.} & & \text{Olefiant Gas.} & & \text{Water.} \end{array}$$

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* Eurizen (Odling). Hydroxyl (Frankland).

$$NH_4Cl + KO,\ HO = NH_3 + KCl + 2HO$$

Chloride of Ammonium. — Hydrate of Potass. — Ammonia. — Chloride of Potassium. — Water.

$$C_4H_6O_2 + O_4 = C_4H_4O_4 + 2HO$$

Alcohol. — Oxygen. — Acetic A. — Water.

$$KO,NO_5 + H_8 = NH_3 + KO,\ HO + 4HO$$

Nitrate Potass. — Hyd. — Ammonia. — Hydrate. Potass. — Water.

$$NH_3,\ C_2HO_4 = C_2N + 4HO$$

Oxalate of Ammonia. — Cyanogen. — Water.*

Also that water seemed to require to be represented with 2 atoms of H, because in the replacement of the latter by other elements, the H was frequently removed in halves by two successive stages, *e.g.*—

$\left.\begin{matrix}H\\H\end{matrix}\right\}O_2$	$\left.\begin{matrix}H\\H\end{matrix}\right\}O_2$	$\left.\begin{matrix}H\\H\end{matrix}\right\}O_2$
$\left.\begin{matrix}H\\K\end{matrix}\right\}O_2$	$\left.\begin{matrix}H\\Et\end{matrix}\right\}O_2$	$\left.\begin{matrix}H\\Cl\end{matrix}\right\}O_2$
$\left.\begin{matrix}K\\K\end{matrix}\right\}O_2$	$\left.\begin{matrix}Et\\Et\end{matrix}\right\}O_2$	$\left.\begin{matrix}K\\Cl\end{matrix}\right\}O_2$
$\left.\begin{matrix}Et\\K\end{matrix}\right\}O_2$	$\left.\begin{matrix}Et\\Me\end{matrix}\right\}O_2$	$\left.\begin{matrix}Cl\\Cl\end{matrix}\right\}O_2$

Double Atoms of Oxygen.

Moreover that in all series of compounds of oxygen with two other kinds of matter, *e.g.*, oxyacids and oxysalts, the O increases by 16 parts at each step, *e.g.*—

HCl	H_3P	H_4C_4 Ethylene
$HClO_2$	Cl_3PO_2	$H_4C_4O_2$ Aldehyd
$HClO_4$	H_3PO_4	$H_4C_4O_4$ Acetic A.
$HClO_6$	H_3PO_6	$H_4C_4O_6$ Glycolic A.
$HClO_8$	H_3PO_8	

The grounds of Dalton's preference for the water ratio 1 : 8 over 2 : 16 were therefore weakened, and it was suspected

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* Many more instances may be drawn from organic chemistry, *e.g.*

$$HNO_6 + C_{20}H_8 = C_{20}H_7(NO_4) + 2HO$$

Nitric A. — Naphthalin. — Nitronaphthaline. — Water.

$$H_3PO_8 + C_4H_6O_2 = H_2(C_4H_5)PO_8 + 2HO$$

Phosph. A. — Alcohol. — Phosphovinic A. — Water.

$$HNO_6 + C_{12}H_7N = C_{12}H_6(NO_4)N + 2HO$$

Nitric A. — Aniline. — Nitraniline. — Water.

$$NH_3,C_4H_4O_4 = C_4H_3N + 4HO$$

Acetate of Ammonia. — Acetonitrile. — Water.

from this frequent association in certain cases of 16 parts of O, that they were inseparable, and that the indivisible atoms of O weighed 16 not 8, so that the two oxides of hydrogen were not

$(O = 8)$	HO	and	HO_2
	Water		Binoxide of Hydrogen,
but $(\Theta = 16)$	$H_2\Theta$	and	$H\Theta$

the *horizontal bar* through a letter being used to indicate that the worth of the symbol is *doubled.*

Duplication of Atomic Numbers.

This duplication of the atomic number of oxygen has involved a corresponding doubling in the case of C , S and its congeners and most of the metals, in fact, in all the elements except the halogens, except the metals of the alkalies including H, except Ag, Th, the nitrogen family, B and Au; and this altered series of numbers (*vide* page 12 *infra*) is now styled preeminently the *atomic numbers*, while the terms *combining* or *equivalent* number are now confined to the old list on page 6.

Advantages.

The desirability of this change (which if for mere novelty's sake would be an unmitigated evil) is increased by the considerations—

I. That if an atom of H be taken as the unit of reference, the *specific gravity* of gaseous or vaporous elements is represented by the *new atomic number* ;[*] of those compound vapours or gases whose atom occupies 2 volumes, by half that number.[†]

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[*] This is equivalent to the statement "that all elementary gases contain the same number of atoms in the same volume under like conditions of temperature and pressure." Exceptions occur in the case of P, As ; the free molecules of P and As appear to consist of 4 atoms arranged on the ammonia type

$$P'''\begin{cases}P'\\P'\\P'\end{cases} \;\&\; As'''\begin{cases}As'\\As'\\As'\end{cases}$$

one of the atoms only playing a triatomic part, but no condensation taking place in volume as indeed might be expected since like matter is associated. Thus as each atom occupies half a volume, the molecule occupies two according to the general law. Exceptions likewise occur in the cases of NH_4Cl and PCl_5 which each occupy four volumes ; this has been explained by the dissociation of the elements into

$$\begin{array}{ccccccc} NH_3 & + & HCl & \text{and} & PCl_3 & + & Cl_2 \\ \text{2 vols.} & & \text{2 vols.} & & \text{2 vols.} & & \text{2 vols.} \end{array}$$

at the high temperature required for their volatilization and measurement. The same explanation (dissociation) likewise may apply to H_2SO_4 NH_4CN NH_5S each occupying 4 volumes at high temperatures; but in a paper laid before the Chemical Society of London, May, 1866, I have ascribed these and other abnormalities to the use of a supposedly incorrect formula for the expansion of gases by heat.

[†] This is equivalent to the assertion "the molecular weight of gaseous bodies is double their specific gravity."

II. The *specific heat* of gaseous or vaporous elements is the reciprocal of the *new atomic number*; of solid elements is proportional to that reciprocal.*

III. The small changes introduced into the symbolization of compounds, have reconciled under similar formulæ previously observed but unexplained cases of *isomorphism*, *e.g.*,

$$FeS_2 \text{ and } Fe\left\{\begin{matrix}S\\As\end{matrix}\right. ;\ Ag_2S \text{ and } Cu_2S;\ Mn_2\Theta_7 \text{ and } Cl_2\Theta_7;$$
$$Ca C\Theta_3 \text{ and } KN\Theta_3$$

IV. These small numeric changes have manifested certain undoubted *analogies*, *e.g.*, of the oxides of N and Cl, of the alcohols and water, of the hydrated bases and acids, which were concealed by the old formulæ where O = 8.

V. These changes have accounted naturally for the diversities in the *basicity of acids*, *e.g.*, have shown from the mere shape of the formula why $HN\Theta_3$ $H_2C\Theta_3$ $H_3P\Theta_4$ are respectively mono—, bi—, tri-basic as containing one, two, three atoms of hydrogen replaceable by a mono-equivalent base.

Objections.

On the contrary, the formulæ of some *few* oxydised bodies, *e.g.*, Suboxide of Silver Ag_2O or $Ag_4\Theta$, Arsenic Acid AsO_5 or $As_2\Theta_5$, &c., &c,, may be represented more simply by the old method, as also the oxychlorides and those equations representing the interchange of oxygen with the halogens; and Faraday considers that the electrolysis of water proves it to be a protoxide HO containing only one equivalent of each element, for such compounds alone, according to his experience, are electrolytic.

Transformation of Formulæ.

Rules for converting formulæ from the old to the new system of atomic weights:—

I. If either *all* or *none* of the elements involved in the formula are perissads,† the formula will remain unchanged, the atomic weights in the former case being all identical, in the latter all doubled, and therefore relatively of the same proportionate value; *e.g.*, NaCl remains unaltered, Fe_2O_3 becomes $Fe_2\Theta_3$.

II. If the formula contain both perissads and artiads,‡ as

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* Exceptions occur in the case of the solids C, B, Si which admit of allotropism; when the primary forms and various atomic weights of these elements shall have been clearly determined, they may also perhaps be found to conform to the general rule; many groups of solid compounds having a similar chemical constitution likewise follow this rule.

† Elements of uneven atomicity, vide succeeding list.

‡ Elements of even atomicity, vide succeeding list.

$C_4H_6O_2$ or $NaCl$, $PtCl_2 + 6HO$, halve the number of atoms of each artiad, or if fractions of atoms are thus introduced, double the number of atoms of each perissad. Thus

$$C_4H_6O_2 = \text{Ꞓ}_2H_6\text{Ɵ} \text{ and } KCl, PtCl_2 + 6HO = K_2Cl_2\ PtCl_4 + 6H_2\text{Ɵ}$$

Atomicity. The new atoms, some of which have been doubled, are obviously no longer equivalent to each other, and a closer scrutiny into their saturative and substitutive worth has led to their classification as mono—, bi—, tri—, tetr—, pent—, hex—, hept—, oct—atomic, according as they are capable of replacing 1, 2, 3, 4, 5, 6, 7, or 8 atoms of hydrogen respectively.*

Thus instances may be found in which $\text{Ƒe}''$ $\text{Ɱg}''$ biatomic are replaced by two atoms of a monatomic element, such as Ag' or K' , or $\text{Ꞩ}''$ by two of Cl' or I' , or B''' by three of K', &c., where it will be observed that we indicate the number of the atomicity by a superfix.

Classification of Elements. The following table shows this arrangement together with the new atomic numbers :—

PERISSADS.†

MONADS.			
Fluorine	F'	=	19
Chlorine	Cl'	=	35·5
Bromine	Br'	=	80
Iodine	I'	=	127
TRIADS.			
Nitrogen........	N'''	=	14
Phosphorus	P'''	=	31
Arsenic	As'''	=	75
Antimony	Sb'''	=	122
Bismuth........	Bi'''	=	210

MONADS.			
Hydrogen	H'	=	1
Lithium	L'	=	7
Sodium	Na'	=	23
Potassium	K'	=	39
Rubidium	Rb'	=	85
Cœsium	Cs'	=	133
Silver	Ag'	=	108
TRIADS.			
Thallium	Tl'''	=	203
Aluminum ..	Al'''	=	27·5
Gold	Au'''	=	196
Boron	B'''	=	11

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* It will now be understood why Williamson proposes to express the equivalents symbolically in a fractional form, thus $\frac{\text{Ɵ}}{2}, \frac{N}{3}, \frac{\text{Ꞓ}}{4}$ exhibiting at the same moment the numerical worth of the equivalent, and the atomicity of the element.

† Slight differences of opinion still exist respecting this grouping into natural families, and the position of individual members relatively to the rest; it must be understood also that the atomicity may be *occasionally* a sub-multiple of the number assigned, or even some other number belonging to the same great sub-kingdom ; the subject is not yet fully investigated.

ARTIADS.[*]

DYADS.

Oxygen	O''	=	16
Sulphur	S''	=	32
Selenium	Se''	=	79·5
Tellurium	Te''	=	129

Chromium	Cr''	=	52·5
Manganese	Mu''	=	55
Iron	Fe''	=	56
Cobalt	Co''	=	58·5
Nickel	Ni''	=	58·5
Copper	Cu''	=	63·5
Uranium	U''	=	120

Magnesium	Mg''	=	24
Zinc	Zn''	=	65
Cadmium	Cd''	=	112
Mercury	Hg''	=	200

DYADS.

Calcium	Ca''	=	40
Strontium	Sr''	=	87·5
Barium	Ba''	=	137
Lead	Pb''	=	207

HEXADS.

Molybdenum	Mo^{vi}	=	96
Vanadium	V^{vi}	=	137
Tungsten	W^{vi}	=	184

Atomicity not well known	Thorinum	Tr^{iv}	=	197
	Rhodium	Ro''	=	104
	Ruthenium	Ru''	=	104
	Glucinum	G''	=	9
	Yttrium	Yt''	=	64
	Cerium	Ce''	=	92
	Lanthauum	La''	=	92
	Didymium	Dy''	=	96
	Columbium	Cb^{iv}	=	195

TETRADS.

Carbon	C^{iv}	=	12
Silicon	Si^{iv}	=	28
Titanium	Ti^{iv}	=	50
Zirconium	Zr^{iv}	=	89·5
Tin	Sn^{iv}	=	118
Tautalum	Ta^{iv}	=	138
Palladium	Pd^{iv}	=	106·5
Platinum	Pt^{iv}	=	197
Iridium	Ir^{iv}	=	198
Osmium	Os^{iv}	=	199

The elements have here been grouped according to their atomicity (which, according to some chemists, varies in some cases within certain limits) in two[†] great families, named by Odling *Perissads* respectively, and *Artiads* (*i.e.* Odds and Evens περισσός and ἄρτιος).

Williamson more strictly distinguishes them as elements of which (α) an *even* number only (β) *either an even or an odd* number can enter into the composition of any *molecule*.

Williamson's definition tacitly assumes Laurent and Gerhardt's law of even numbers (which will be found illustrated below), viz., "the sum of the atomicities of the elements contained in any molecule, simple or compound, is an even number," it necessitates, moreover, the explanation of a new term *molecule*, which differs somewhat from *atom.*

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[*] The atomicity of a compound radicle seems to be the difference of he atomicities of its constituents; thus of $P^{v}O''_4$ it is 4 × 2 — 5 = 3, of $S''O''_2$ it is 2 × 2 — 2 = 2, of $N^{v}O''_2$ it is 5 — 2 × 2 = 1.

[†] A third Periss-Artiads is sometimes added, to include such elements as iron and its congeners, which have now an odd, now an even atomicity, e.g., Hg, Cu, Cr, Mn, Fe, Ce, U, Ro, Ru.

Molecule and Atom Contrasted.

Thus, while an *atom** is the smallest quantity of an element or compound that can be *associated* with others or transferred from one compound body to another, *e.g.*, the H or Cl in HCl, the Mg and Θ in MgΘ; a *molecule*† is the smallest quantity that can exist *isolated in a free state* or stand by itself uncombined, *e.g.*, H_2, Cl_2, Θ_2 in the following reactions

$$\begin{aligned} \mathrm{Mn\Theta_2} + 4\mathrm{HCl} &= \mathrm{MnCl_2} + 2\mathrm{H_2\Theta} + \mathrm{Cl_2} \\ \mathrm{H_2\Theta} + \mathrm{Zn} &= \mathrm{Zn\Theta} + \mathrm{H_2} \\ 2(\mathrm{KCl\Theta_3}) &= \mathrm{KCl\Theta_4} + \mathrm{KCl} + \mathrm{\Theta_2}\,‡ \end{aligned}$$

In the case of nearly all compound bodies, excepting the monatomic radicles, and of some elements also as Hg Cd Zn, the atom and molecule are identical in weight; but in the case of H Cl Br I N Θ S Se, and the monatomic radicles, the latter is double the former, in P and As quadruple, *vide* note page 10.

Law of even Numbers.

This explanation of molecule will now enable the student to understand the following exemplifications of the "Law of Even Numbers" quoted above, and the latter law will in turn add definitiveness to the idea of molecule. Neither H', $H'\Theta''$, $N'''\Theta$, $N'''\Theta_2''$, $C_2''\,H_5'$ are molecules according to Laurent and Gerhardt, because the sums of their atomicities viz. 1, $1 + 2$, $3 + 2$, $3 + 2 \times 2$, $2 \times 2 + 5$ are not even numbers; they are also not molecules according to our previous definition because they are insufficient to stand isolated as either the agent or resultant of a chemical action; but H_2, $H_2'\Theta''_2$, $N_2'''\Theta_2''$, $N_2'''\Theta''_4$, $(C_2''H_5')_2$ satisfy both these conditions, and are therefore the molecules, as does also any one of the formulæ on page 22. We thus see the truth of the somewhat paradoxical saying, "a body can contain an *uneven* number of atoms of a given element, but in order to form it we must employ an *even* number of free atoms;" *e.g.*, PCl_5 the supposed molecule of pentachloride of phosphorus

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* Sometimes termed elementary atom.

† Sometimes termed molecular atom.

‡ Additional instances are given below in the new notation.

$$\begin{aligned} Cl_2 + 2KHO &= KCl + KClO + H_2O \\ 3Cl_2 + 6KHO &= 5KCl + KClO_3 + 3H_2O \end{aligned}$$

Or again

$$\begin{aligned} CuH + HCl &= CuCl + H_2 \\ Ag_2O + 2(HO) &= 2Ag + H_2O + O_2 \end{aligned}$$

contains an odd number of atoms of each of its constituents, but it must be formed from $PCl_3 + Cl_2$ two free atoms of Cl being employed.*

Volume of Molecule.

It is believed that the molecule of almost all gaseous or vaporous bodies occupies the same volume as a molecule of H viz., two volumes,† and this important law regulates greatly our choice of the rational formulæ, expressing the constitution of volatilizable bodies.

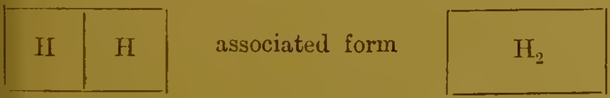
These remarks lead us to a consideration of the

LAWS OF COMBINATION OF VAPOUR-VOLUMES.

Combination by Volume.

I. When any number of volumes of the *same* element are associated (*e.g.*, four half volumes of phosphorus or arsenic to form the free molecule) no condensation takes place, but the resulting volume is the sum of the constituent volumes.

Example (a) Molecule of Hydrogen.



II. When *unlike* vapours as A, B chemically combine, then in all such possible combinations, m volumes of A unite with n of B to form two volumes or a molecule; where m and n are exceedingly simple integers rarely exceeding 5, and usually prime to each other.

ILLUSTRATIONS.

$$m = 1, n = 1.$$

If one volume of each constituent is combined, *no condensa-*

---

*HgCl, HgBr, HgI (each occupying 2 vols.) have either anomalous vapour densities, or the law of even numbers does not hold in their case unless Hg be admitted sometimes monatomic.

† A convenient standard for measuring the *volumes* of gases is the French *litre* = 1,000 cubic centimetres, and for measuring their *weights* by Hofmann's *kilocrith* (χίλιοι, κριθή) *i.e.*, the weight of one litre of hydrogen at 0° C and 760 millimetres barometric pressure; thus, 1 kilocrith = 1000 criths = ·09 grammes nearly.

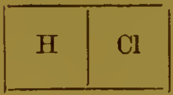
The absolute constitution of a gaseous compound, either by volume or weight, may thus be concretely expressed from a mere inspection of its formula, coupled with a knowledge of the atomic number, *e.g.*, 2 litres of NH_3 ammonia is seen to contain

by volume	by weight
1 litre Nitrogen	14 kilocriths N
3 litres Hydrogen	3 kilocriths H

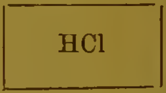
tion will occur on chemical union, as the resultant will stil occupy two volumes.

Example (β)

Hydrochloric Acid.



united form

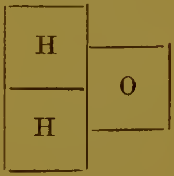


In all other cases but the two foregoing *condensation wil generally take place.*

$$m = 2, n = 1.$$

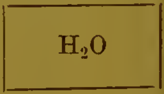
When two volumes of A are combined with 1 of B th resultant will condense into two volumes.*

Example (γ)



united form

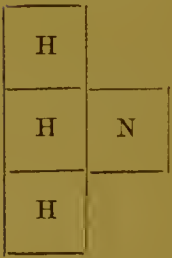
Steam.



$$m = 3, n = 1.$$

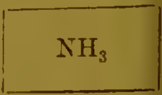
When 3 volumes of A are combined with 1 of B the resultan will again condense into two volumes.†

Example (δ)



united form

Ammonia.



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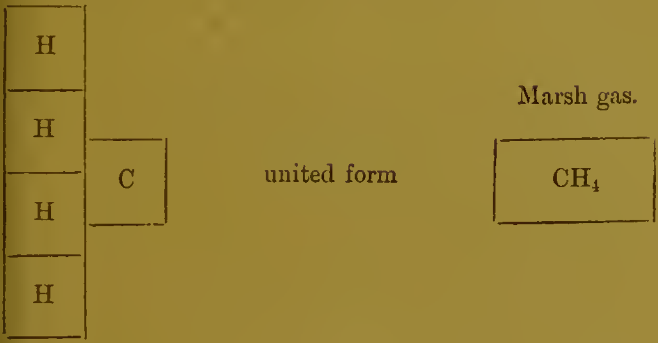
* Exception: 2 vols. of Hg combined with 1 vol. of S, form 3 vols. (HgS without contraction.

† Exceptions: 3 vols. of O combined with 1 vol. of As yield 1 vo of As_2O_3; so also $AlCl_3$ occupies 1 vol., but it is more probable that Al_2C is the molecule, in which case the vol is regular.

$$m = 4, n = 1.$$

When four volumes of A are combined with one of B, the esult is two volumes.

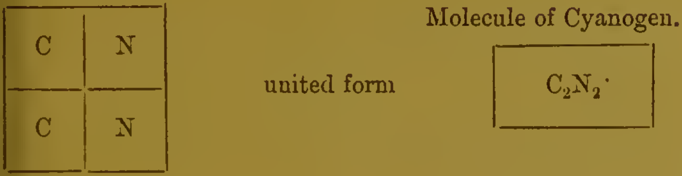
Example (ϵ)



$$m = 2, n = 2 \text{ (not prime to m).}$$

The four volumes are condensed into two.*

Example (ζ)



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* To this hitherto unrecognised type may also be referred

$S_2 + Cl^2 = S^2Cl^2$ (2 vols.)
$SO_2 + Cl_2 = SO^2Cl^2$ (2 vols.)
$CO + Cl^2 = COCl^2$ (2 vols.)
$C_2H_4 + Cl_2 = C^2H^4Cl^2$ (2 vols.)

d many other instances; an exception to the rule occurs in the case of O^2 (4 vols.) not yet explained; the other irregular cases have been umerated in previous footnotes. Before quitting the subject of vapour lumes, Cl_2O_3 (3 vols.) and Cl_2O_4 (4 vols.) must be added to the list of own abnormalities to render it complete. When we recollect that the or 20 anomalies mentioned are all that have been discovered in a rutiny of some thousands of aeriform fluids, we must feel persuaded at the sagacious law of Gerhardt is worthy of confidence.

Gerhardt's Types.

Gerhardt has chosen examples (α) (β) (γ) (δ) viz., HH, HCl H_2O, H_3N as the *types* or patterns on which he believes nearl all chemical substances to be constructed.

By the substitution of equivalent atoms of other elements c radicles for the H, Cl, O and N, respectively involved in on or more of these molecular types (taken either singly or cor jugately) an almost infinite variety of analogous products represented.

Thus one atom of H′ may be replaced by one of K′, Na′ Li′ Ag′ &c., and the monatomic base radicles; two atoms H by one of a biatomic element or radicle, &c.

One atom of Cl′ may be replaced by one of F′, Br′, or the monatomic chlorous radicles, *e.g.*, Cy.

One of O″ by one of S″, Se″, Te″ or the biatomic elemen or radicles.

One of N‴ by a triatomic member, as P‴, As‴, Sb‴, Bi‴ &

Gerhardt's Classification.

Thus under one or more molecules of the HH type includes the metals, the alcohols, the hydrides of bo these, and of the aldehyds, the free halogens and the hydrog acids.

Under one or more molecules of the H Cl type he includ the free halogens, the fluorides, chlorides, bromides, iodid cyanides of the metals or base radicles; the oxychloride chloric ether, aldehydic chloride, and their analogues.

Under the water type $\left.\begin{matrix}H\\H\end{matrix}\right\}O$ he includes the oxid sulphides, selenides, tellurides &c., hydrated and a hydrous, basic and acid; the oxygen and sulphur salt the alcohols, ethers, simple and compound, the aldehy and mercaptans.

Under the $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}N$ ammonia type, he places the triaton elements, the nitrides, phosphides, &c.; the amides a amines, and alkalamides.

Additional groups of higher complexity (chiefly organic) supposed to be obtained by the association of different typ *e.g.*, one of water with one of ammonia; the conjug molecule, however, is found still to contain only *two vap volumes.*

The majority of chemists now reduce the number of pes (α) (β) (γ) (δ) to three, by regarding the HH and HCl tterns as one; other persons add to the HCl, H_2O and H_3N fourth (ε) which introduces tetratomic bodies, viz., H_4C. arsh gas.*

Unitary System.

This *substitutional* method (or rather method of double de- mpositions) Gerhardt called the *Unitary system*, all compound dies being considered as "unique molecules," not as ordi- rily either oxides or salts. The latter, he asserted, show cording to the ordinary notation only one aspect of the dy, and the meaning of only one or two reactions, not of all e possible chemical metamorphoses.

These dualistic formulæ, he said, which affect to explain e proximate constitution of salts err by excess of assumption, d are unwarranted, since we know nothing of the proximate t only of the ultimate constitution of compounds; my rmulæ are not framed on the supposition that salts contain acid and a base, and finally their symbols all represent a ngle molecule.

Quitting Gerhardt's unitary method, of which specimens ill be given shortly, it is now necessary that we should plain the difference between the common or dualistic view d the binary.

Dualistic System.

According to the *ordinary or dualistic* hypothesis which has evailed from the earliest development of the science, the ements combine in couples to form compounds, these com- unds again uniting by twos (hence the name dualistic) to rm more complex substances; most of the latter and some the former are called salts.

Salts are subdivided, therefore, into two classes; to the one long all salts made up of an oxygen acid and an oxygen se, which are hence called oxygen salts, *e.g.* NaO, SO_3; the other class are reckoned all salts formed by the ion of the radicle in hydrogen acids with some metal, g., NaCl. These binary salts are called haloid (ἅλς, sea-salt, ος, species) because they are constructed upon the same model sea-salt.

Binary System.

As the two classes of salts are not dissimilar in properties, avy considered that they might both be referred to the tter pattern, and that instead of regarding oxygen salts as mposed of an oxide of a metal and the anhydride of an

---

[*] I believe their number may be increased with advantage to compre- nd two or three other simple cases of volume combination; *vide* paper omitted to the British Association, 1866.

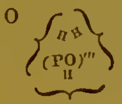
oxygen acid, they might be considered as composed of a metal and a compound radicle having the same chlorous or electronegative chemical relations as the radicles in the hydrogen acids.

According to this view, which has been called the *Binary theory*, sulphuric acid and the sulphates are represented as compounds of a radicle sulphion SO_4 not yet isolated, thus H,SO_4, $CaSO_4$ and are termed sulphionides; in like manner nitric acid and the nitrates are conjectured compounds of a radicle NO_6 nitration, thus H,NO_6 K,NO_6 and are termed nitrationides in the same manner as the similar compounds o Cl or Cy are named chlorides or cyanides.

The chief objection to the binary hypothesis (as, indeed partially to the unitary) is that it requires us to grant the existence of many radicles, which if not imaginary, are (to say the least) as yet undiscovered, but it affords the best explanation of the results of electrolysis, and is in other particulars more philosophic than the dualistic system; the latter, however, is still preferred by many teachers of the elements of the science, as the formulæ exhibit in some instances the actua constituents which may be used in the manufacture of a compound, thus aiding the memory.

Three Notations Contrasted.

The following instanees of common substanees expressed ymbolically according to the three systems, will serve as ommentary upon the preceding paragraphs.

ames.	Dualistic (atoms not doubled)	Binary (atoms not doubled)	Binary (atoms doubled)	Unitary (atoms doubled)	
ydrate of otassa	HO + KO			$\left.\begin{matrix}H\\K\end{matrix}\right\}O$	1 Water molecule
ılphu- c Acid	HO,SO^3	H,SO_4	H^2,SO^4	$\begin{matrix}H\\(SO_2)''\\H\end{matrix}\begin{matrix}\}O\\\}O\end{matrix}$	2 Conjugated water molecules
ersul- ıate of Iron	$Fe^2O^3,3SO^3$	$Fe_2,(SO_4)_3$	$Fe'''_2(SO^4)_3$	$\left.\begin{matrix}Fe_2'''\\(SO_2)''_3\end{matrix}\right\}O^6$	6 Conjugated water molecules
Sul- ıate of Soda	NaO, SO^3	Na,SO^4	Na_2,SO^4	$\begin{matrix}Na\\(SO_2)''\\Na\end{matrix}\begin{matrix}\}O\\\}O\end{matrix}$	2 Conjugated water molecules
itrate Silver	AgO, NO^5	Ag,NO_6	Ag,NO_3	$\left.\begin{matrix}Ag\\NO'_2\end{matrix}\right\}O$	1 Water molecule
:ther	C_4H^5,O			$\left.\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right\}O$	1 Water moleculo
cohol	$C^4H^5,O+HO$			$\left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}O$	1 Water molecule
ibasic ·hos- horic Acid	$3HO,PO_5$	H_3,PO_8	H_3PO_4		3 Conjugated water molecules
				or $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}(PO_4)'''$	1 Ammonia molcculo
tasso- ·oride plati- ıum	$KCl+PtCl_2$	KPt,Cl_3	K_2Pt,Cl_6	$\left.\begin{matrix}K_2\\Pt^{iv}\end{matrix}\right\}Cl_6,$	6 Conjugated hydrocl: acid mols.

Gmelin's Nomenclature.

A change in the *nomenclature* of substances has been adopte by Gmelin, which prevails on the Continent, viz., 1° to writ (as is commonly done when symbols are used) the base o electropositive constituent with an adjectival terminatio before the acid or electronegative constituent; thus sodi chloride NaCl instead of chloride of sodium. 2° Where ther are two well defined compounds of the basylous and chlorou constituents, to attribute the adjectival termination ic to tha which has least base, —ous to that which has most, in th manner which has been long adopted with the non-metalli oxides and acids, *e.g*,,

$N_2\Theta$ Nitrous Oxide	$\text{Ꞙ}e\,Br_2$ Ferrous Bromide
$N\Theta$ Nitric Oxide	$\text{Ꞙ}e\,Br_3$ Ferric Bromide

The following list will exhibit the method proposed mor perfectly than any amount of verbal description.

MOLECULES OCCUPYING TWO VOLUMES.

$H_2\Theta$	Hydric Oxide
$K_2\Theta$	Potassic Oxide
$\text{Ȼ}u_2\Theta$	Cuprous Oxide
$\text{Ȼ}u\Theta$	Cupric Oxide
$Bi_2\Theta_3$	Bismuthic Oxide
$\text{Ꞙ}e_2\Theta_3$	Ferric Oxide
$K_2\text{Ꞩ}$	Potassic Sulphide
$(\text{Ȼ}_2H_5)_2\Theta$	Ethylic Oxide
$(\text{Ȼ}_2H_4)\Theta$	Ethylenic Oxide
$HN\Theta_3$	Hydric Nitrate
$Fe(N\Theta_3)_2$	Ferrous Sulphate
$Fe_2(N\Theta_3)_6$	Ferric Nitrate
$Fe_2(\text{Ꞩ}\Theta_4)_3$	Ferric Sulphate
$H_2\text{Ꞩ}\Theta_4$	Hydric Sulphate
$HK\text{Ꞩ}\Theta_4$	Hydro-potassic sulphate
$H_3P\Theta_4$	Hydric Phosphate
HCl	Hydric Chloride
$FeCl_2$	Ferrous Chloride
$\text{Ꝑ}tCl_4$	Platinic Chloride.

DECIMAL OR METRIC TABLES.

Decimal Measures.

In France the standard of lineal measure is one ten-milliont part of the terrestrial arc from the equator to the pole = 39·37 inches, and is called a *metre;* it serves as the basis of a measurement.

The Latin prefixes deci- centi- milli- joined to any measure, dicate $\frac{1}{10}$th, $\frac{1}{100}$th, $\frac{1}{1000}$th of the same.

The Greek prefixes* deca- hecto- kilo- myrio- indicate 10, 00, 1,000, 10,000 times the basal quantity.

The standard of solid or liquid weight is the *gramme*= eight of a cubic centimetre of distilled water = 15·444 grains.

Hofmann proposes that the standard of gaseous weight ould be the *crith* = weight of a cubic centimetre of hydrogen.

The standard of capacity is the *litre* = 1 cubic decimetre = 1·028 cubic inches.

These brief remarks will suffice to introduce the following bles frequently used in chemical computations.

Prefix.	Lineal inches.	Grains.	Grains.	Cubic Inches.
1 milli...	·039	·015	·000001	·061
1 centi...	·393	·154	·000013	·610
1 deci ...	3·937	1·544	·000138	6·102
1 ,, ...	39·371	15·444	·001383	61·028
1 deca...	393·71	154·44	·013837	610·28
1 hecto	3937·1	1544·4	·138378	6102·8
1 kilo ...	39371·	15444·	1.383782	61028·
1 myrio	393710·	154440·	13.837824	610280·
	metre	gramme	crith	litre
	Length.	WEIGHT. Non-gaseous.	Gaseous.	Capacity.

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* δέκα, ἑκατόν, χίλιοι, μύριοι.

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SOME TIGHT
GUTTERS

TABLE(S)
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GUTTER